

FMCW Radars for Planetary Landers: Lessons Learned from the Huygens Radar Altimeter

R. Trautner¹, H. Svedhem¹, J.-P. Lebreton¹, D. Plettemeier ²,
N. Floury¹, P. Couzin³

¹Research and Scientific Support Department (RSSD), ESA/ESTEC, Post Bus
299, 2200AG, Noordwijk, The Netherlands

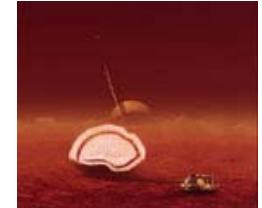
²Technical Univ. of Dresden, Chair of Electromagnetic Theory and EMC,
Helmholtzstraße 9, D-01062 Dresden, Germany

³Alcatel Space, 100 Boulevard. du Midi, BP99-06322 Cannes La Bocca, France



Presentation Overview

- FMCW Radars – Principle
- The Huygens Altimeter: Design, Interfaces, Signal Processing
- Altimetry and Surface Backscatter Measurements
- Surface Topography and Spectral Data
- Atmospheric Backscatter Measurements
- Design and Performance Improvements
- Radar Operations: Altimetry and Science
- Conclusion

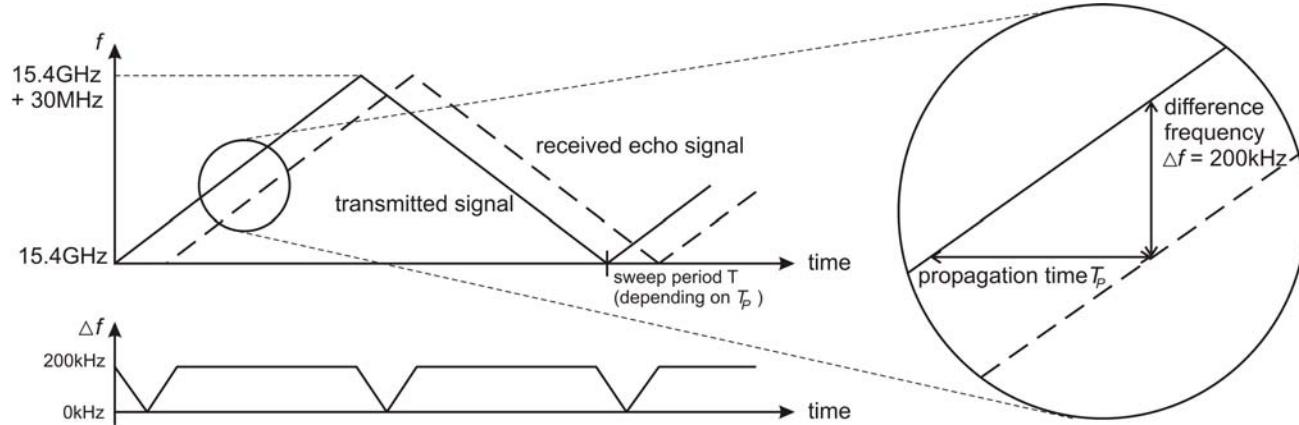


FMCW principle

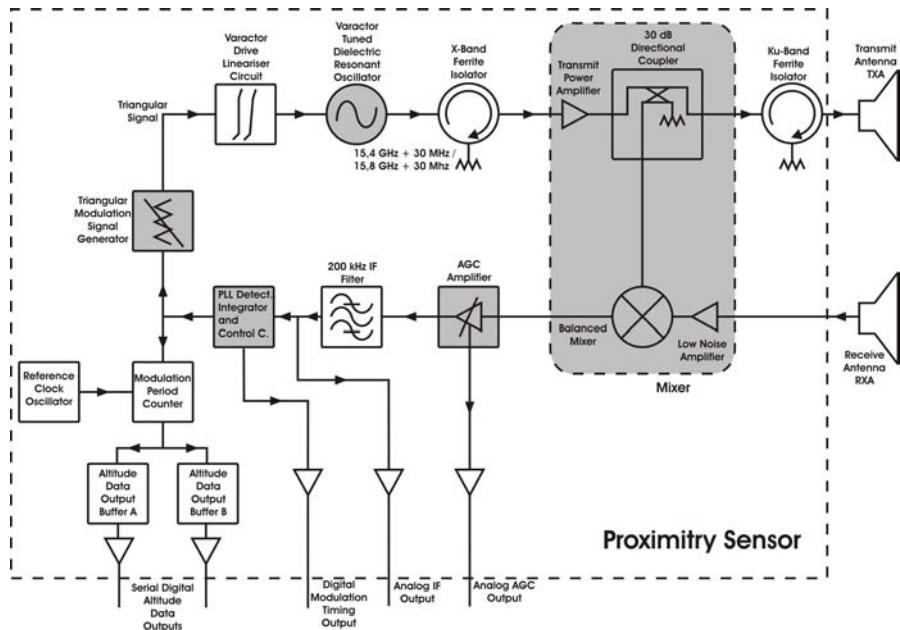
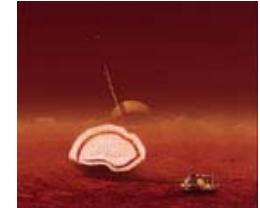
- constant power output
 - frequency modulated by triangular waveform
 - received frequency mixed with transmitted freq
 - difference freq is kept constant at defined IF frequency
- => triangular signal frequency prop to 1/ Alt

Applications

- altimeters
 - cloud radars
- => simple to implement
=> light and reliable



Huygens HRA: Design



HRA design features

- Probe system, **not payload**
- Fully redundant system
- Tx frequencies 15.4 GHz, 15.8 GHz
- Output power ~ 100 mW
- FM bandwidth 30 MHz
- Input to Mixer Noise temp ~ 263 K
- 15 kHz IF BW, 200 kHz IF freq
- 50 dB AGC gain range
- Design alt range 10 km (initial), up to ~ 60 km (after modifications)

Data products

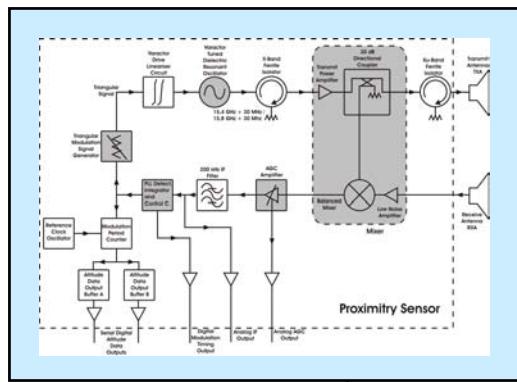
ALT data (digital interfaces), **AGC data** (analogue HK), **IF data** (PWA science)

Scientific utilization was result of Huygens PS initiative, GR issues etc. - late implementation

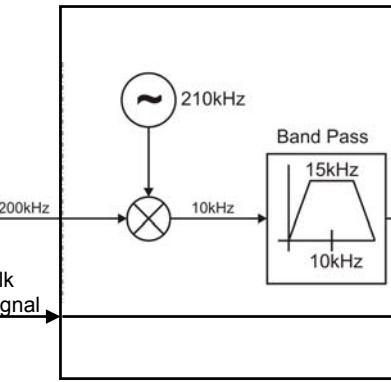
Huygens HRA: Interfaces & data processing



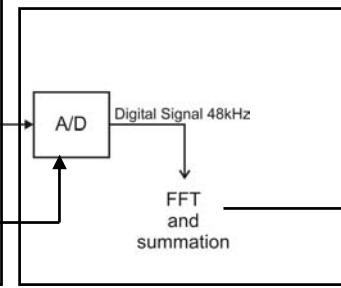
HRA



RAE

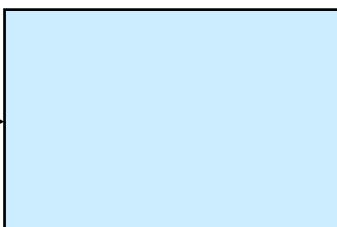


HASI-PWA



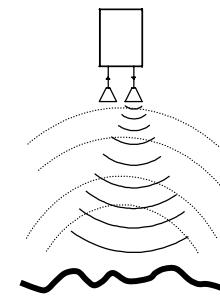
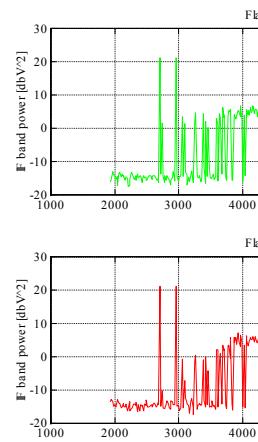
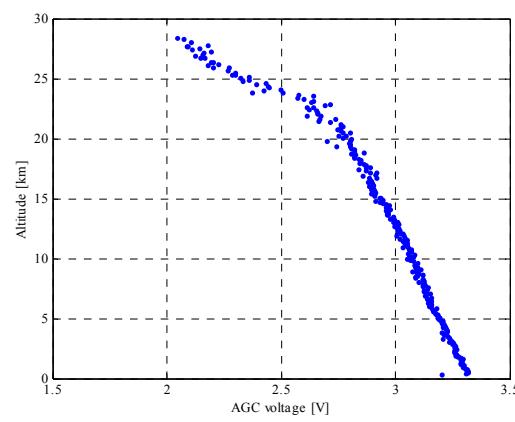
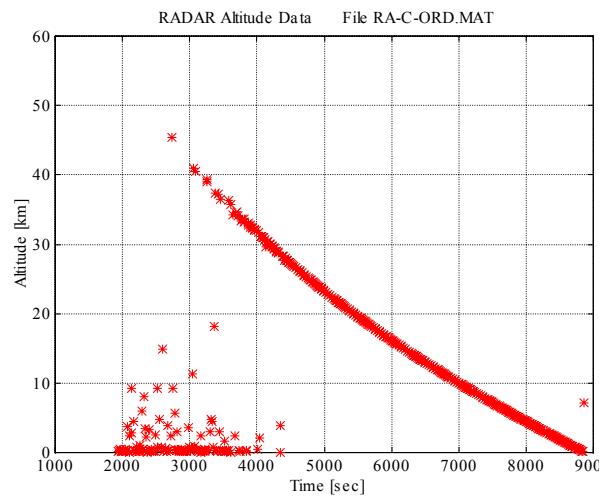
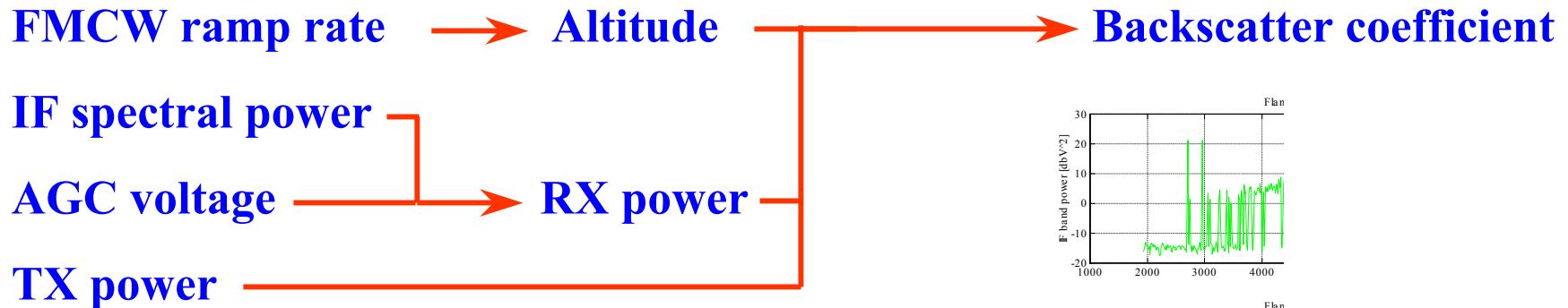
IF spectra
PWA alt

AGC data
ALT data

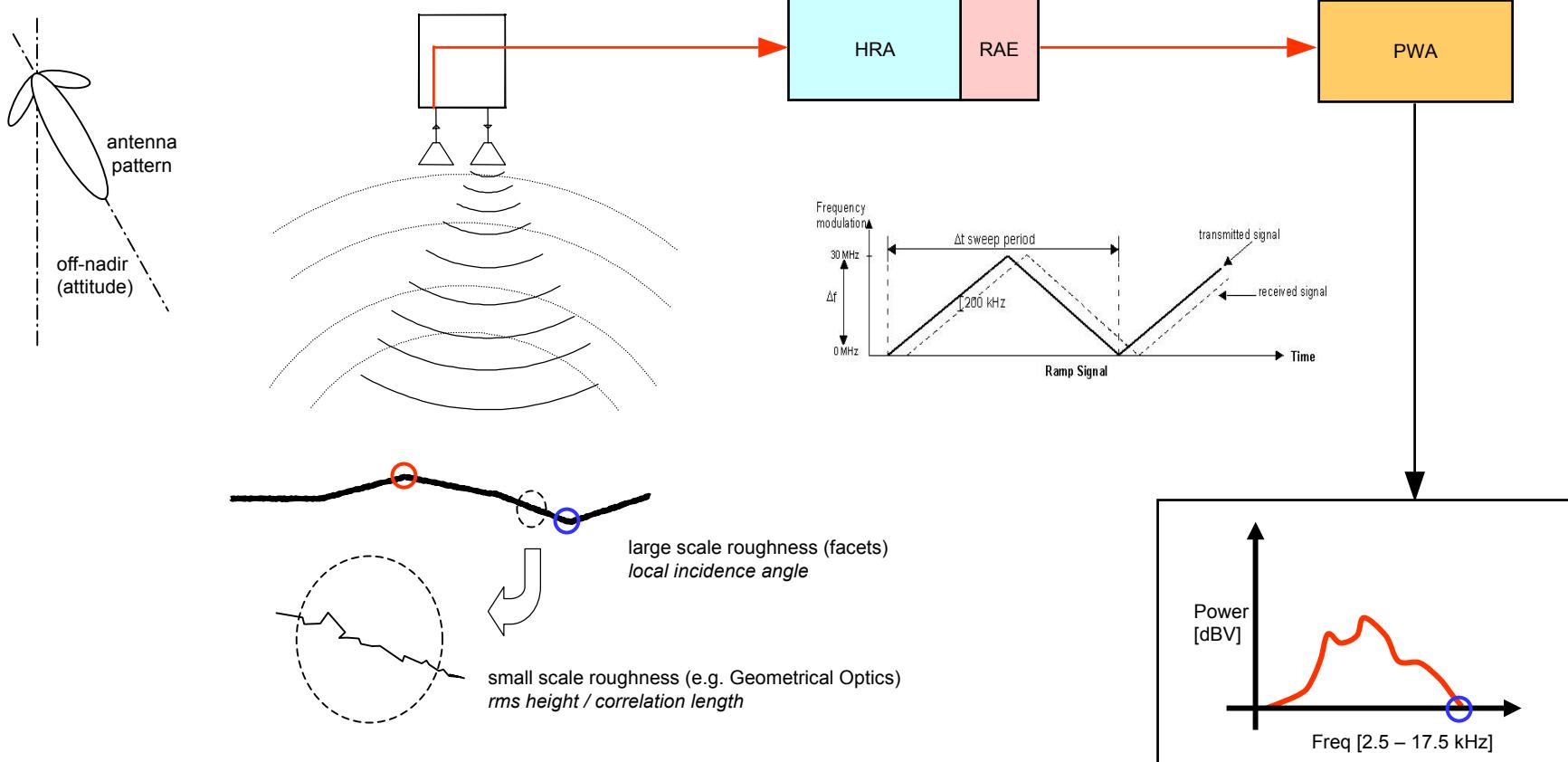
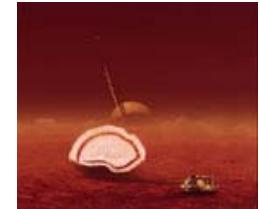


HK data

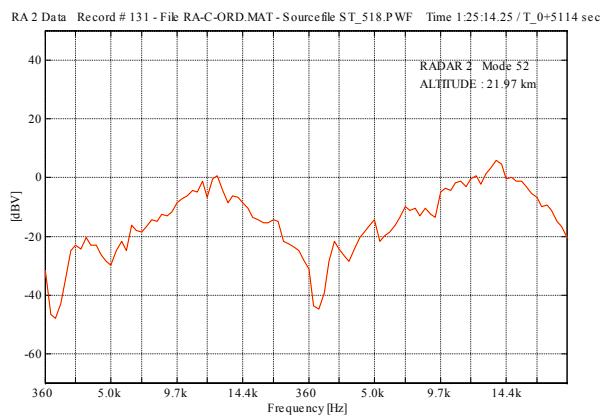
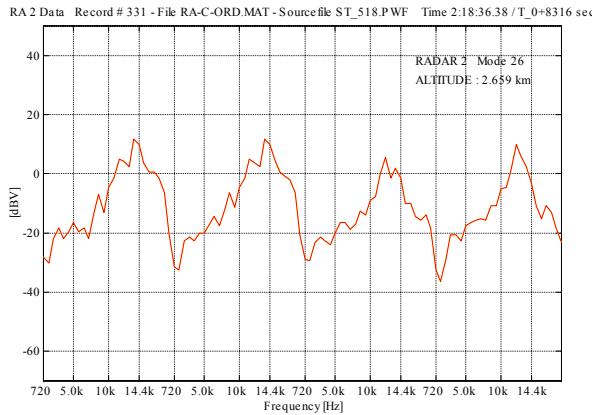
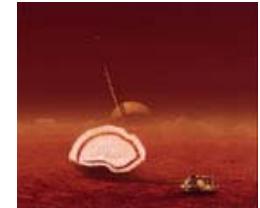
PWA data



Surface topography and spectral data (1)

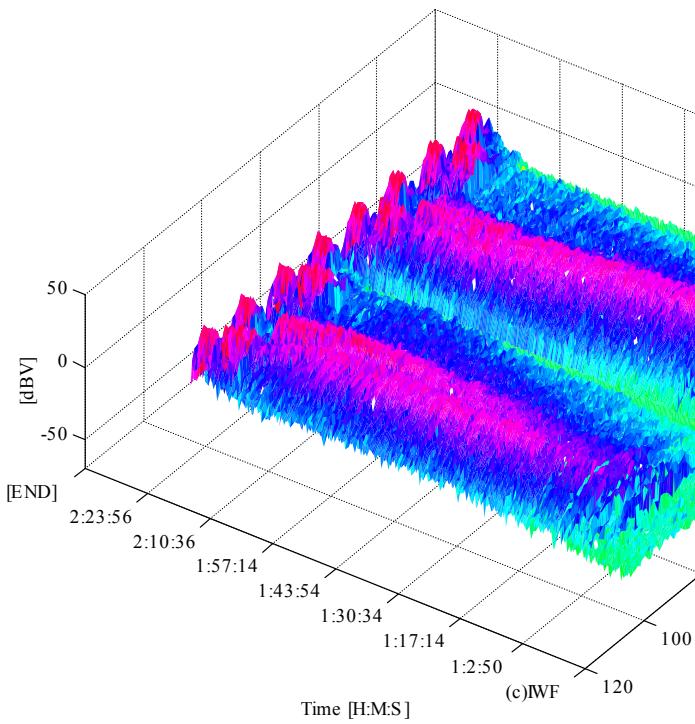


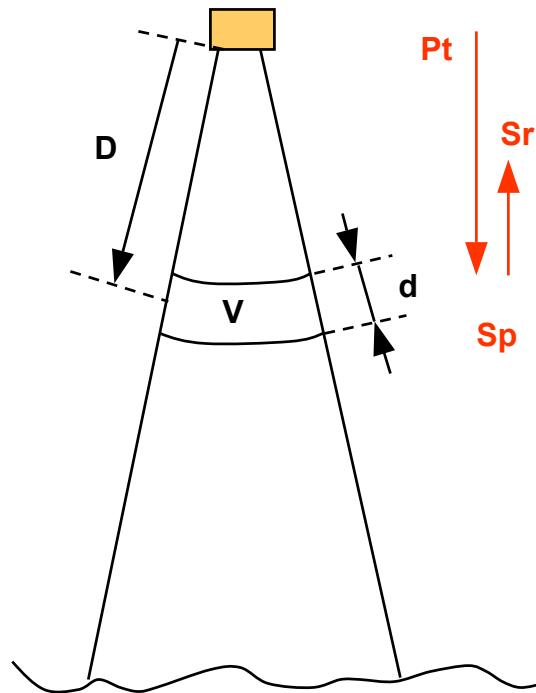
Surface topography and spectral data (2)



Huygens data

RADAR Data Spectra RM 13/26/52 File:RA-C-ORD.MAT Data Status: CUT C/





Emission and backscatter

Pt: transmitted power

Sp: prop. $1/D^2$

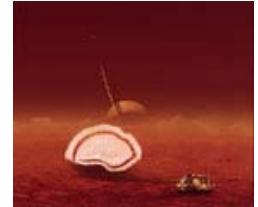
Sr: prop. $1/D^4$ for 1 particle

V: prop. D^3

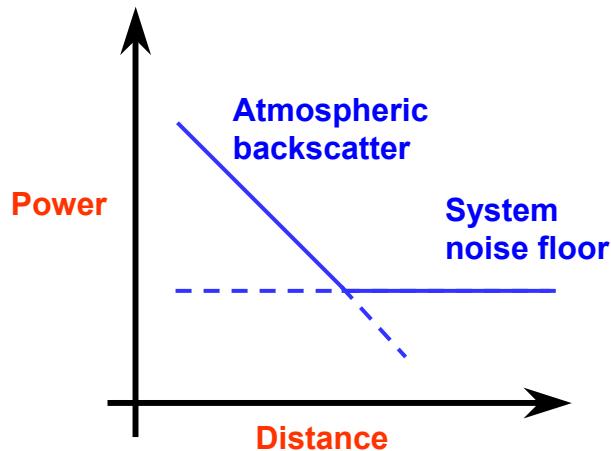
\Rightarrow Sr prop. $1/D$, Pr prop $1/D$
for backscattered signal

Important factors:

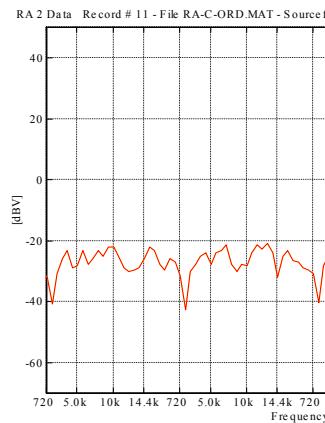
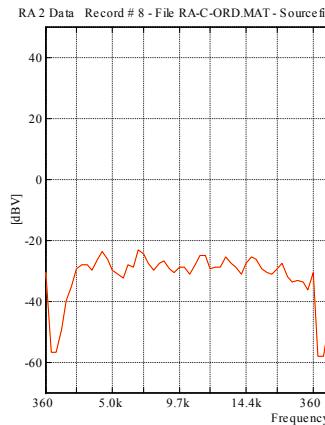
- Transmitted power
- Z – factor (total backscatter cross-section)
- Receiver chain noise level and interference



Aerosol backscatter



Huygens data:



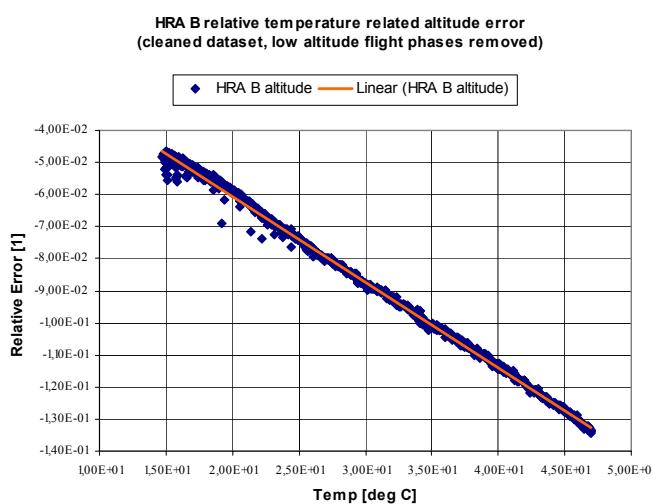
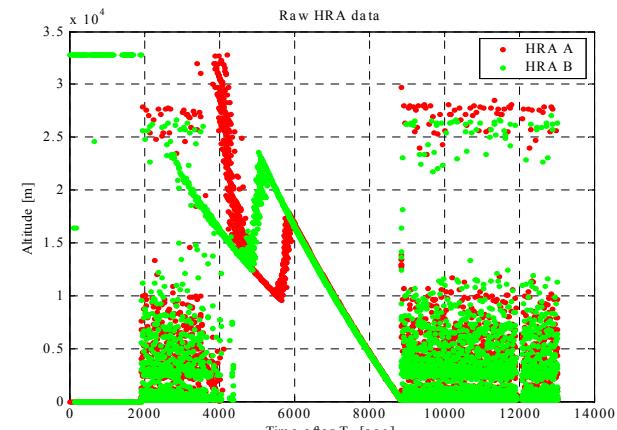
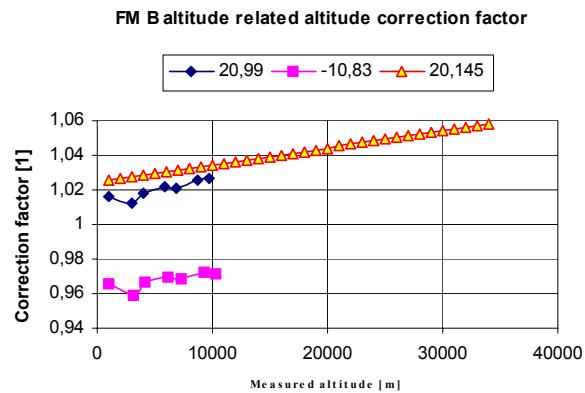
- **1/D signal visible:** Z parameter and aerosol properties can be derived
- **1/D not visible:** upper limits for Z can be derived

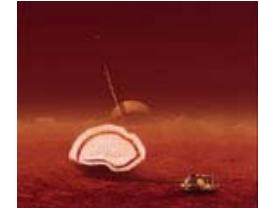


Altimeter Function

Design problems:

- Ramp rate counter accuracy (RC)
- Digital I/F bitshift error
- Temperature effects > calibration
- Altitude related effects > calibration
- Supply voltage impact > lack of HK data
- HRA alt used by CDMS above tested alt

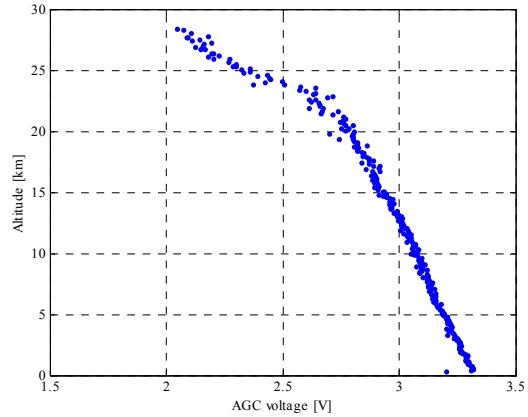




Surface Backscatter Measurements

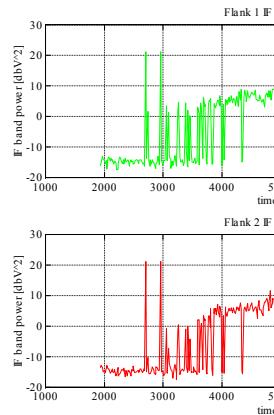
Design problems:

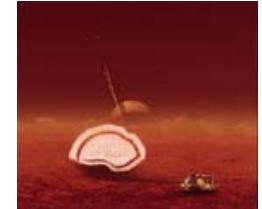
- AGC / IF sampling times decoupled -> interpol.
- Lack of attitude data > sigma(0+/-x)



Calibration problems

- Some temperature effects unknown
- AGC calibration accuracy not dramatic
- Supply voltage > lack of HK data





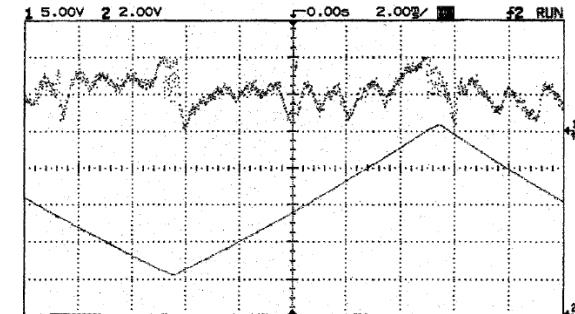
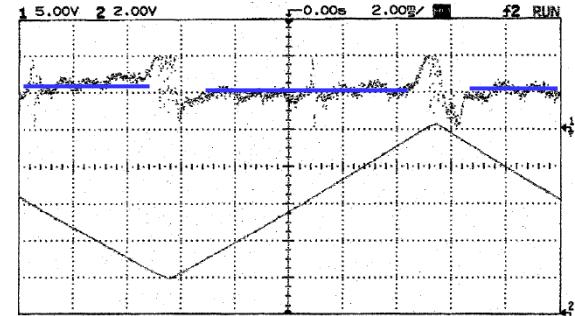
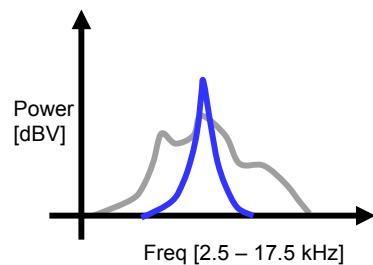
Spectral Data for Topography Investigation

Design problems:

- Linearity of FM ramp very bad (after improvement !)
=> circuit concept
- Spectral resolution in PWA not very good
- Lack of attitude data

Calibration problems

- IF filter characteristics not calibrated





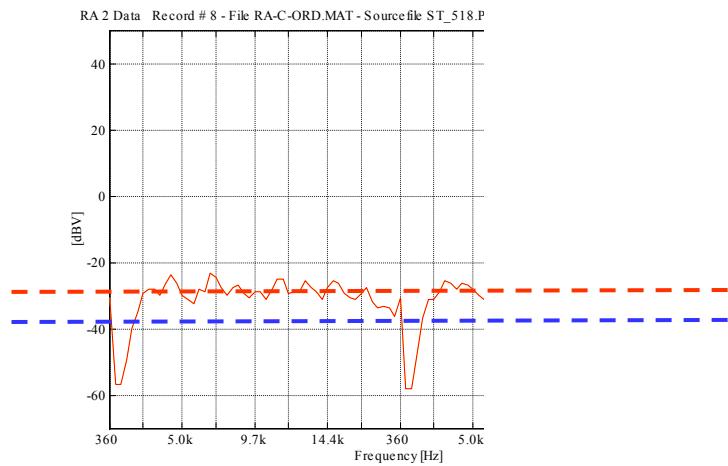
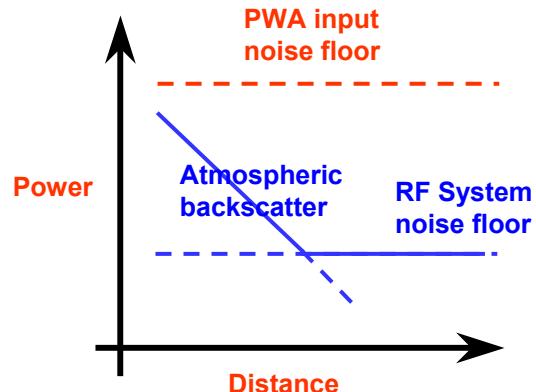
Atmospheric Backscatter Measurements

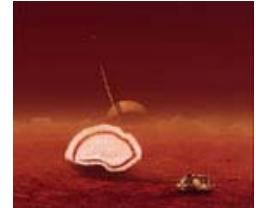
Design problems:

- Input stage noise temp ~ 263 K
= - 39 dBV (PWA)
- Measured: $\sim - 29$ dBV = 2600 K !!
- no atm. BS data from lower alt
(radar locked)

Calibration problems

- No / incomplete noise measurement data





Radar operations and new capabilities

Altitude measurement interleaved with science mode

- Once in lock, radar would not provide atmospheric data
- Radar can be ‚kicked out‘ of lock to perform one atmospheric scan, then lock again

All relevant data sampled by same source

- Altitude, AGC, IF power

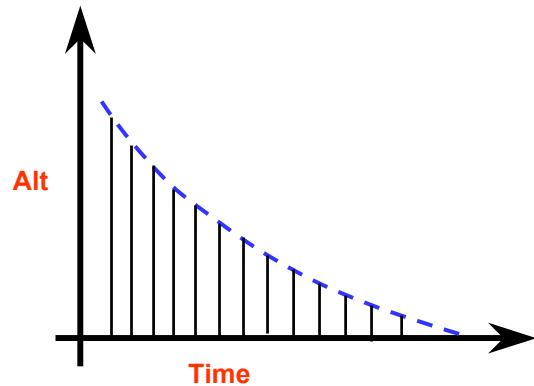
Advanced / new capabilities (specific hardware ?)

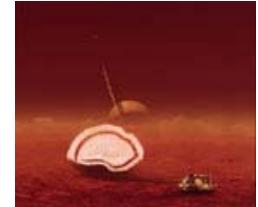
- Switching of radar beamwidth / direction -> radar mapping ?
- Surface mode ?
..... depends on priorities (system vs. instrument)

Huygens



FCMW ‘kicked’ frequently





FMCW Radar Performance and Data Products

- Reliable, simple, lightweight system; range few 10m to few 10km
- Data products: Altitude, descent velocity, surface properties, atmospheric properties, topography, and others (wind, ..)
- Can deliver important science at very little additional mass / cost
- Output improved with auxiliary data (attitude, etc.)

Improvements for Future Applications

- A number of technical issues, but ... Most important:
- Use combined System / Instrument approach => Management issue
- Identify possible scientific utilization already during study phases
- If justified:
 - Use instrument specs in design requirements
 - Perform full science oriented calibration